



Tropical cyclones detection using GPS radio occultation data

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Publication date:
2011

Document Version
Publisher's PDF, also known as Version of record

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Citation (APA):
Biondi, R., Neubert, T., Peng Ho, S., & Syndergaard, S. (2011). *Tropical cyclones detection using GPS radio occultation data*. Poster session presented at IUGG : Earth on the Edge: Science for a Sustainable Planet, Melbourne, Australia. <http://www.iugg2011.com/>

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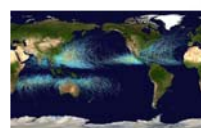
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Objective

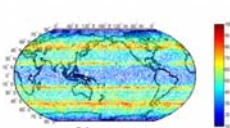
The tropical deep convection usually redistributes the water vapor from troposphere to stratosphere and perturbs the thermal structure in the upper troposphere and lower stratosphere, which has noticeable impacts on the radiation balance of the atmosphere. Understanding the mechanisms that control these processes, will help for improving the cloud parameterization in the climate models and the severe weather forecasting schemes.

Case selection

We selected the tropical cyclone (TC) tracks and they were compared with GPS/MET, SAC-C, CHAMP, GRACE and COSMIC Radio Occultations (ROs). 1194 coincidences were found between ROs and TCs considering a time window of 3h and a space window of 300km from the eye of the TC, 77% of coincidences are coming from COSMIC project. Then we selected all the cases with available co-located radiosondes.



TC tracks



RO coverage

	GPSMET	SACC	CHAMP	GRACE	COSMIC	Total
1995	1					1
2001	13	9				22
2002	27	28				55
2003	29					29
2004	40					40
2005	33					33
2006	12					12
2007	9	18	194			221
2008	20	22	335			377
2009	14	14	211			225
Total	140	180	54	0	0	1194

Number of coincidences

Datasets & Methods

Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) on board of CALIPSO satellite is a two-wavelength (532 nm, 1064 nm) polarization-sensitive lidar that provides high-resolution vertical profiles of aerosols and clouds, with footprint of 100m, horizontal resolution of 333m and vertical resolution between 30m and 60m depending on the altitude. These measurements are used for the determination of the cloud top altitude.

The radiosondes (RAOBs) in FSL (Forecast System Laboratory) format, are part of the National Oceanic and Atmospheric Administration Earth System Research Laboratory (NOAA-ESRL) radiosonde database, and they are used as in situ validation of the temperature profiles, when close enough to the GPS RO.

The GPS radio occultation technique uses a GPS satellite transmitting the signal and a Low Earth Orbit (LEO) satellite receiving the signal to profile the atmospheric refractivity with high vertical resolution. Temperature, pressure and water vapour are derived via a one-dimensional variational (1Dvar) approach involving the refractivity and the ECMWF model.

Methodology

$$n(r_p) = \exp \left(\frac{1}{\pi} \int_{a_p}^{\infty} \frac{\alpha(a)}{\sqrt{a^2 - a_p^2}} da \right)$$

α : bending angle
 a : impact parameter
 r_p : tangent radius
 n : refractive index

$$N = (n - 1) \cdot 10^6$$

$$N = 77.6 \frac{p}{T} + 3.73 \cdot 10^5 \frac{e}{T^2}$$

N : refractivity
 p : pressure
 T : temperature
 e : water vapor pressure

$$\alpha_{anomaly} = 100 \cdot \frac{\alpha_{TC} - \alpha_{Clim}}{\alpha_{Clim}}$$

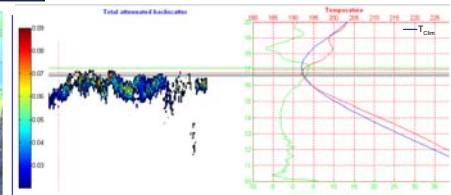
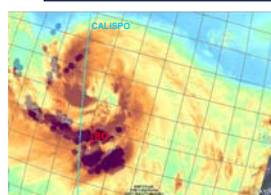
$$T_{anomaly} = (T_{TC} - T_{Clim})$$

$\alpha_{anomaly}$: bending angle anomaly
 α_{TC} : TC bending angle
 α_{Clim} : climatological bending angle
 $T_{anomaly}$: temperature anomaly
 T_{TC} : TC temperature
 T_{Clim} : climatological temperature

The climatological reference (Average) is a profile obtained averaging all the ROs within a 1 degree box (Geo-location) with a standard vertical resolution of 50 meters (Interpolation) applied to the Level 2 data (atmPrf&wetPrf)



Analyses – Krosa 2007

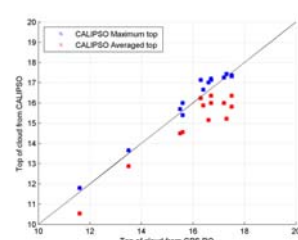


The water vapor Brightness Temperature (BT) from the Geostationary Meteo Sat (GMS) at the same time and in the same location as the RO, was lower than 205K and the 11 microns BT was lower than 200K, suggesting an inversion due to the convective clouds. During the TC in that area, more than 1500 strokes were detected from World Wide Lightning Location Network (WWLLN) in the same area of the RO.

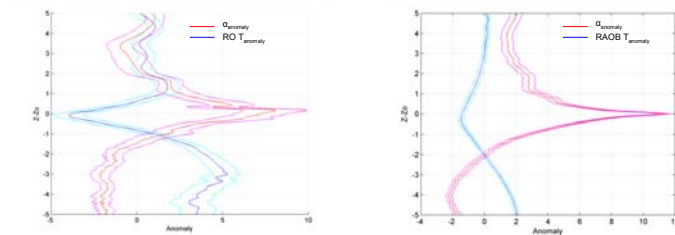
The bending angle anomaly (right panel) profile shows a double positive spike in the UTLS, the lower spike at 17.2 km of altitude, 600m above the lowest coldest point of 192K and another spike a couple of km above corresponding to a second temperature minimum of 199K. Comparing these profiles with the CALIOP total attenuated backscatter at 562 nm (right panel), it is clear how the altitude of the lowest bending angle spike almost corresponds to the maximum altitude of the cloud top which is 16.9 km. The tropopause from AIRS is located at 15.4 km of altitude which is more than 1 km below than the tropopause from the GPS RO climatology (16.7 km).

Statistics

Tropical cyclone	Distance [km]	Time [min]	Basin
RUMBA	27	82	West Pacific
ALBERTO	27	119	Atlantic
KRISTY	18	98	East Pacific
PERPAH	80	7	West Pacific
PABUK	15	82	West Pacific
MAN-YI	92	68	West Pacific
KROSA	18	39	West Pacific
PABUK	79	58	West Pacific
NAURI	84	85	West Pacific
HAINA	68	37	Atlantic
PHANFONE	20	88	West Pacific
ELIDA	3	102	East Pacific
LOWELL	47	84	East Pacific



We have found 13 ROs during TCs co-located with CALIPSO within a time window of 2 hours and a space window of 100 km. The bending angle anomaly spike is highly correlated to the maximum cloud top during the storm. The correlation is 0.98 and the rms is 365 meters. The correlation is still high (0.93) when we compare the bending angle anomaly spike with the averaged altitude of the storm, but a higher bias is evident in this case.



The left panel shows the bending angle anomaly (together with the standard deviation of the mean) and the correspondent temperature anomaly in the range from 5 km below to 5 km above the top. Below the top, the troposphere is warmer than the climatology and the bending angle anomaly is negative, then, it rapidly increases, becoming positive and reaching the maximum amplitude exactly at the cloud top where the temperature is colder than the climatology. The right panel shows the same plot for 246 cases where the ROs are co-located with RAOBs.

Uncertainties

- Different perturbations act at the same time affecting the bending angle
- Difficult co-location between different instruments and TCs
- Different vertical resolutions

Conclusions

- Bending angle anomaly profile shows a clear TC signature in the UTLS
- Bending angle could be used as an indicator of TC top altitude

Contact and Reference

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Biondi, R., Neubert, T., Syndergaard, S., Nielsen, J. K.: Radio occultation bending angle anomalies during tropical cyclones, Atmospheric Measurement Techniques, 4, 1053–1060, 2011, doi:10.5194/amt-4-1053-2011